3703

NOTES ON ARTILLERY FIRE, CARRIAGES, &c.,

FOR THE USE OF THE

GENTLEMEN CADETS

OF THE

ROYAL MILITARY COLLEGE OF CANADA.

BY

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The following notes on Artillery, supplementing the text books in use at the Royal Military College, are compiled chiefly from Colonel Nicholson's essay on Shrapnel fire and from the official text books.

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CHAPTER I.

VARIOUS NOTES ON FUZES, &c.

It is more difficult to make a slow composition burn regularly than a quick one. Adding saltpetre and sulphur, and diminishing the amount of meal powder, makes fuze composition burn more quickly.

A shrapnel shell ought to have a fuze that will burst, at at least $\frac{1}{4}$ seconds; even this gives about 100 yards intervals.

The 5, 15 and 30 second fuzes, latest patterns, can be burst at every $\frac{1}{4}$ second; the 9 seconds at every $\frac{1}{2}$ second.

Armstrong E, and the modern time and percusion fuze, can be set to burst at any point.

Increased atmospheric pressure makes time fuzes burn more rapidly, each *diminution* of pressure equal to one inch increases the time of burning about $\frac{1}{30}$th. Now, 1 inch is about equivalent to 1,000 feet in altitude; therefore, about 5,000 feet above the sea the 30 second fuze would burn 35 seconds.

Fuzes that have been kept long burn slowly, unless the climate is extremely dry; fuzes that had been upwards of a year in a very dry climate burnt at about the normal rate, 7,000 feet above the sea. Remember all data as to guns, fuzes, &c., are prepared in England, and at the sea level.

A good time fuze ought to have the following characteristics:—

1st. It must be regular in lighting and burning.
2nd. It must be quickly and easily arranged to burst at various intervals of time.
3rd. These intervals should be as small as possible.
4th. The "No. 1" ought to be able to set it after it is in the shell.
5th. He ought to be able to alter its setting either shorter or longer.
6th. It must keep well in store.
7th. It must not be too complicated or expensive.

8th. It must not be liable to give premature explosions or blind shell.

9th. It must ignite instantaneously and with the lowest charges that will be used.

BLIND SHELL.

The chief causes of blind shell are as follows:—

1. From the fuze not igniting.

2. From the fuze being bored too long and being knocked out or extinguished on graze.

3. From the primer of a shrapnel shell becoming covered by a foreign substance.

4. From the hole not being bored through into the composition, or from the fuze being set on the "bridge" of a metal one.

5. From the shell not being full.

PREMATURE EXPLOSIONS.

Prematures are more serious than blind shell, as artillery frequently fire over their own troops, and premature explosions would be very discouraging to them.

PREMATURES DUE TO FUZE.

1. A fuze improperly bored or set.

2. A fuze not home from shell being too full.

3. A fuze of old "common guage" may be too high in gauge, and one of the side holes be above the shell.

4. An old pattern S.B. fuze without paper lining when the composition has shrunk from the wood.

PREMATURES FROM CAUSES CONNECTED WITH THE SHELL.

1. Bad lacquer, iron or grit in the shell, or in the larger natures the bag being omitted.

2. From the shell not being full.

3. From a weak or defective shell.

All fuzes are now made to the G.S. gauge, and in the case of the older patterns of ammunition for 7-inch R.B.L. guns adaptions have to be used as they are of a large obsolete gauge. Time fuzes for rifled guns can be used for S.B. guns, but not so with the percussion fuzes.

A wooden time fuze will nearly always act as a percussion on direct impact.

For field guns percussion fuzes ought to act instantaneously. For breaching purposes there out to be a slight delay in the action so as to allow the shell to penetrate, the "Direct action" and the new large and small percussion fuze are not quite as quick as the R.L. fuzes for field service.

For some cases a fuze with a delay arrangement of about ½ a second will be advantageous, though if the shell is liable to glance it would be a disadvantage.

The fuze can be either in the base or nose of a shell.

A time and percussion fuze is now used with the B.L. guns for it is thought if the time part does not burst the shell before graze, it is best to burst then, as the shell rises rapidly and its flight is uncertain after graze.

CHAPTER II.

CARRIAGES.

Principles of Construction of Field Artillery Carriages.

The following qualities are necessary in a field artillery carriage:

First, and most important, is *mobility*, for without this, in a high degree, field artillery would be of little use.

Stability, so that in any movement required, even on rough ground, it may not overturn.

Strength, *durability* and *simplicity*, are, of course, a great importance; and *convenience of transport* is peculiarly necessary for British artillery, that has to be sent to each and every quarter of the globe.

Mobility is influenced by several things, viz.:

By the "traction" or "draught," that is, the power requisite to put it in motion, by its capability of reversing, and by its power of passing objects.

It is necessary then to have the draught as light as possible, therefore the load must be as light as possible, that is, the gun and ammunition being fixed, the carriage must be as light as possible; and also the load must be properly distributed over the axles. The fore carriage having, as it were, to make the track, is hardest to drag, therefore the load ought to be rather less on it than on the rear axle. At the same time, if too much weight is thrown on to the rear wheels they will sink, and thereby increase the weight on the whole. The two axles must be long enough to make both tracks exactly the same, so that the front wheel prepares the track for the rear.

The diameter of the wheels must be a maximum, and the diameter of the axle a minimum. In order to increase the leverage over friction; 5 feet has been selected as the most suitable.

Lastly, the angle of traction must be as favourable as possible.

The height of a horse's collar being practically fixed, the only thing we can vary is the height of the point of attachment of traces to the carriage. We find about $6\frac{1}{2}°$ the best.

The carriage must also be capable of reversing very sharply, therefore it must be a minimum length, and the angle through which the fore carriage can sweep, a maximum.

The mobility of a carriage is also influenced by its power of passing obstacles. The size of wheels and inclination of traces influence this, but are more properly considered under the head of lightness of draught. The mode of attachment of fore and hind carriage materially affects this power. The fore carriage should be able to move vertically about the point of attachment, so that it may move in that direction, to some extent, independent of the hind carriage.

Mobility must be accompanied by stability.

Stability is influenced by the number of points on which the carriage rests, and the position, vertical and horizontal, of the centre of gravity with regard to those points.

The carriage being level, the vertical distance should be a minimum, and the other a maximum, that is, the C. G. should be as low and the carriage as wide as possible.

Stability in reversing is influenced by the height and mode of connection of fore and hind carriages, and the height of traces. When advancing, the vertical from C.G. should always fall within the figure joining the points of support. The upsetting angle for the carriage packed is about 35°.

The material used must be the strongest consistent with lightness. It must stand well the effects of shot striking it, rough usage, the action of climate, and must not deteriorate in store. Wrought iron has superceded wood, being much more durable, and scarcely any heavier, for a given strength. It is not so elastic, and hence does not absorb so much of any strain put on it as wood, and also it is easily put out of shape; and hence there is a loss of strength through change of form, therefore stronger iron is used than is absolutely necessary to resist a particular stress. Steel is now being used for the latest carriages.

The carriage should have as few parts to get out of order as possible, and any part should be easily repaired if necessary, and all parts and fittings should, as far as possible, be interchangeable with other carriages.

Carriages should take to pieces and stow away conveniently on board ship, and the length of carriage should be a minimum, not only for mobility but to make a column of route as short as possible.

THE GUN CARRIAGE AND LIMBER.

The present form has been arrived at as fulfilling the foregoing con-

ditions; as convenient for bringing the gun into action; as furnishing a stable carriage for the gun when in action; as allowing a supply of ammunition to be carried with the gun; and as admitting of a portion of its detachment being carried on it if necessary.

We will now investigate, as shortly as possible, the various strains exerted on the gnn carriage when the gun is fired.

We may consider the discharge as simply producing a strain on the bottom of the bore acting along the axis of the piece.

We will also consider the gun as standing on the level, and at any elevation.

The gun carriage being symmetrical with regard to the vertical plane through the axis, we may consider all forces to be spoken of as acting in that plane.

The single force can be resolved into a vertical and horizontal force. Only portions are transmitted to the carriage depending, in amount, on the weight of the gun.

A small part of these is transmitted to the ground, depending on its nature.

These forces we can see will act at the points of attachment of the gun to the carriage, viz.: Trunnion holes, and head of elevating screw.

The horizontal component decreases as the angle of elevation or depression increases.

It exerts itself in two ways, viz.: In recoil, and also in giving a tendency to twist about the point of the trail. Hence, to render this component as harmless as possible, the opposition to this motion should be as slight as possible; that is, the weight should be a minimum; also to reduce the twisting strain the trunnion holes should be as low as possible.

The vertical component acts in an upward or downward direction, the former tending to rend the carriage apart when fired at an angle of depression, and the latter to crush it when fired at an angle of elevation. This tells most on the carriage, especially on hard ground.

In addition to this, it will, as well as the horizontal component, have a tendency to twist the carriage round the point of the trail, either upward or downward, according to the direction of the force.

The body of the carriage being supported by the wheels and the trail, the brunt of this vertical component, if downward, is borne mainly by the axletree, because the axis of the trunnion holes lies vertically very near the axis of the latter.

If the vertical component acts upward, the resistance of the ground is not felt, but the weight of the carriage acting downward as its centre of gravity, tends to tear the carriage apart.

When it acts downward, the resistances of the ground being called into play, they will, in general, be less in total amount than the component itself, the difference varying with the nature of the ground, and being expended on it. In the same manner the ground, by its nature and slope, will influence the recoil, and therefore the amount of the horizontal component spent on the carriage.

Sometimes it is necessary to check recoil, resulting in an extra strain on the carriage.

The trunnions have some play in the holes, and consequently the gun rests on points lower than the axis of the piece; and, consequently, the force of discharge has a moment with regard to the bearing points, which is borne by the screw, and through it to the trail. This portion of the trail has to be extra strong.

The screw has also a strain thrown on it, by the tendency of the whole system to twist round the centre of gravity, and to the reaction.

In guns, such as the cast iron or bronze guns, that have the axis of the trunnions below the axis of the piece, there is a greater strain thrown on the screw and trail, for the blow on the bottom of the bore acting along the axis has a greater moment round the bearing points of the trunnions.

MATERIALS USED IN THE CONSTRTCTION OF CARRIAGES, &C.

First, wood. When a tree is cut across we see the woody fibre arranged round the centre in regular rings, each representing a year's growth, the more solid interior is known as heartwood, the younger portion, next the bark, is sapwood.

Timber should be free from the following defects, viz.: "shakes" radiating from the centre; "cup shakes" or cracks between the annular rings; "upsets," where the fibres have been crushed by compression. "Rind Galls" or wounds received in one of the older layers when young, and grown over in subsequent years. "Dead knots," where a branch has been cut off and its root decayed. "Hollow or spongey" places proceeding from decay. Timber, especially elm and ash, is apt to be "doated" from lying in wet; this defect shews as yellow spots in the wood when sawn.

In good timber, as a rule, the fibre will adhere firmly together, and will not look woolly or clog the saw when cut. When freshly cut it ought to look firm and glistening, a dull chalky look is a sure sign of bad timber.

The closer the annular rings are together the better as a rule will the timber be.

Planks cut from a log will always warp away from the centre of the original tree.

The plank cut exactly through the centre will shrink but not warp.

The chief British woods used in the R.C.D. are oak, ash, elm and beech.

Oak is the strongest, toughest and most lasting. It, however, contains an acid, which corrodes iron in contact with it.

Ash is tough and remarkably elastic. It is used for shafts, handspikes, felloes, &c. It does not stand weather well, and is very liable to suffer from worm.

Elm is a very cross-grained tough wood, therefore it does not splinter. It is also very durable under constant wet.

Beech is a hard, strong wood, but does not stand exposure.

The following foreign woods are used:—

African oak is stronger, heavier and darker than English oak, for which it is used as a substitute.

Sabicu is exceedingly strong, heavy and durable. It is used for parts where rubbing action may be expected and weight is no object, such as the blocks in a rear chock carriage, bollard, &c. It is grown in the West Indies.

Teak, an East Indian and African timber. It possesses great strength, toughness and durability, but splinters readily.
It contains an essential oil that keeps off insects.
It is used for work for foreign stations.

Mahogany is of two kinds, "Honduras," from Central America, and "Spanish," from Cuba and other West Indian Islands.
It is strong in all directions, and keeps its shape under trying circumstances, as to heat and moisture.
Honduras is lighter and inferior to Spanish.

Pine is soft, light and elastic, and is of several kinds.

Pine proper, from the Scotch fir grown in Norway, Sweden and North America. It is red, yellow or white. Yellow alone is used for the interior fittings of waggons.

"Deal" is either white or yellow. It is the produce of the Scotch fir, and is used for ammunition boxes and the boarding of waggons.

Larch is a strong and durable but knotty timber. It is only used for "uphers," or small trees for ladders, &c.

Deal, sawn up, is classed as "planks," "deals," and "battens," according to width, viz.: 11, 9 and 7 in.

The contents of a log are computed, if of oak, elm, or foreign wood, by square measure; if of ash or beech, by round measure; because in these the outer layers are sounder and better than the inner.

Round measure is thus taken $\left\{\frac{\text{mean girth in feet}}{4}\right\} \times$ length in feet = contents in cubic feet.

Square measure. Mean width $\times$ mean depth $\times$ length (in feet in each case,) = contents in cubic feet.

Seasoning timber is expelling, as far as may be, the natural moisture in its pores, this is done either naturally or artificially.

In natural seasoning the wood is cut into planks and exposed to the air, sheltered from rain and high wind. The time required in England is one year for each inch in thickness.

Artificial seasoning is done by subjecting the timber in a chamber to a current of hot-air or steam.

This is much the quicker process but it makes the wood more brittle and less durable than if naturally seasoned.

METALS.

Iron is received by contract in the form of girder **I**, tee **T**, angle **L**, round, square, flat, and plate iron. It is tested in various ways, as to its power of being bent into various shapes, both when hot and when cold.

Round, square and flat is bar iron of that section.

Plate iron has to stand bending when cold, through certain angles, according to its thickness and whether it is bent with or across the grain.

Plate of any thickness must standing, when hot, 120° with grain, and 90° across it.

Both bar and plate iron must stand a strain with the fibre of 22 tons (English) per square inch, and of 18 tons (English) against the fibre.

Malleable cast iron is a term applied to castings of certain iron, which, by an after process of annealing, become a sort of steel. It is very tough and refuses to weld.

Steel is received as "blister," "shear," and cast steel, and tested practically as to its qualities.

There are two principal alloys made use of, all technically known as metal.

(1)	Copper,	86.8	For pipe boxes and sheaves of blocks. This is the hardest, as it contains most tin.
	Tin,	12.4	
	Zinc,	.8	

(2)	Copper,	86.5	For rollers.
	Tin,	10.83	
	Zinc,	2.68	

(3) Copper, 84.2; Tin, 7.9; Zinc, 5.24; Lead, 2.62 — For bearings and nuts of elevating screws, &c.

The usual method of preparing the alloy is to melt all the tin, zinc and lead, with a small proportion of copper, and cast this into ingots. These ingots are broken up and melted, and the rest of the copper added.

LEATHER, ROPE, &C.

The leather used is tanned with oak bark, and not by chemicals. To prove this, cut a small piece and moisten the edge; a black mark down the centre denotes chemical tanning; a brown colour shews oak tanning.

Well tanned leather must not crack when doubled up.

Leather must be periodically dubbed, being first well cleaned. If in use, every three months. If in store once in two years.

Dubbing consists of, train oil, one quart; neatsfoot oil, 4 quarts; olive oil, 2 quarts; tallow, 13 lbs. This is a most useful receipt.

The chief descriptions of leather are: "Hides," from oxen or cows; "strapback," for strapping; "bellows," for bellows of forges (these are dressed in oil;) "mill band backs," for bands of machinery. Also "basils," from sheep skin, for the inside strapping of boxes.

ROPE.

A rope is formed of three strands, each strand of a number of yarns, and each yarn of a number of fibres of hemp. Rope is either white or tarred, and of different sizes, according to the number of yarns. The size is expressed by the circumference in inches.

PAINT.

Lead paint is used for woodwork, as it gives a better body than zinc.

For iron carriages Pulford's black is used, painted over in field carriages with lead.

All new articles receive three coats.

Iron must be cleaned before painting.

Hard stopping is used to stop "shakes"; is made by mixing dry white lead with gold size, 1 lb. of former to 1 gill of latter. It is better than putty for large cracks.

Putty for cracks is made of 1 cwt. of common whitening with 2½ gals. raw linseed oil.

Varnish made of equal parts of boiled oil and copal varnish; is used for the heads of side arms, for rifled ordnance, &c.

Ordinary water proof composition is made of lamp-black, 24 lbs., litharge 13 oz., boiled linseed oil $74\frac{1}{2}$ lbs., beeswax 11 oz.

To preserve bright iron work, mix 3 lbs. tallow and 1 lb. white zinc, and it will preserve bright iron from rust.

WHEELS AND AXLETREES.

A wooden wheel of the old construction has a stock or *nave* of elm, 12 *spokes* of oak, and 6 *felloes* of ash. A cast iron *pipe-box* is fitted into the nave, and the hollow passing through it is enlarged in the middle to hold grease, so that the bearing surfaces extend only to 3 inches from each end; the nave is strengthened by two *nave hoops*.

Wheels are made with a *dish* or inclination of the spokes outwards, to enable them to withstand the lateral thrust that they may be subjected to in passing over uneven ground, when one wheel is often much higher than the other, in which case a pressure is exerted on the nave of the lower wheel, tending to force it outwards; the dish is usually about $\frac{1}{2}$ *in.* for 1 ft. in length of spoke, being $2\frac{1}{2}$ inches in O. P. and 2 inches in N. P. wheels.

The tire of the wheel of the wooden artillery carriage now in the service is composed of 5 short pieces of iron called *streaks*, each of which is placed over the junction of 2 felloes, and secured with 4 bolts and 2 nails; by using a *streak* instead of a *ring* tire a wheel can be repaired in the field, for as the streaks are of small size, they can be transported with a battery, and heated in the ordinary field forge.

The new pattern wheels have metal naves and differ from the above in several points. The metal naves consist of three principal pieces, viz, two flanges and a pipe-box.

The flanges of the wheels, liable to come under fire, are made of gun metal, the others of wrought iron.

The pipe-box is of phosphor bronze. Internally, it is conical in shape and enlarged towards the middle to form a grease chamber, and has grooves cut in the bearing surfaces for the same purpose. Externally, its surface is two conical frustra, base to base; one base is larger than the other, forming a shoulder for the inner flange to rest against; a wrought-iron feather is let into the end of the pipe box on which the inner flange fits, grooves being cut in each for it; this prevents the pipe-box turning in the wheel.

The flanges are of softer metal than the pipe-box; the outer flange is so formed as to give the proper dish to the spokes. The flanges originally were made to overlap the pipe-box, so that a recess was formed for the shoulder of the axletree and for the washer. However, by late orders, these shoulders are to be cut off both axletree and washer and rings of iron are issued to replace them where required. This is necessary because the Indian wheel has not got its flanges overlapping its pipe-box.

The flanges are secured by triangular wrought iron bolts between

each pair of spokes, they are nutted inside. Wedges of wood fit over the bolts, between the spokes to keep out the wet.

The pipe-box is 10 inches long, that is, 3 inches shorter than the old pattern, and in consequence O.P and N.P. wheels are not interchangeable. The spokes are of oak and the felloes of ash.

In the *field* wheel, the ring tire is 3 inches wide, and ⅝ inch thick, and is secured by six bolts, with nuts and collars, one bolt passing through the middle of each felloe. In the *siege* wheel the tire is formed of two rings of the same size as that on the field wheel, shrunk on side by side, and each ring is secured to the felloes by six bolts, the bolts being placed diagonally across the felloes.

The wheels of carriages for all services, not exceeding 3 inches in breadth across the sole of the felloe, will in future manufacture be shod with ring instead of streak tires.

The *track* of wheels is the distance from the outside of one to the outside of the other; it is 5 feet 2 inches for the wheels of field carriages,

Wheels are divided into four classes, termed *siege, field, general service* and *naval* wheels; there are several wheels in each class differing in weight and diameter, but all in a class have the same *pipe-box,* and will therefore fit on the same axle-tree arm.

Wooden travelling carriages hitherto made for our service have wrought iron axle-trees let into wooden beds; the axle-tree bed is fitted underneath the brackets and trail by *housings,* and is attached to the carriage by two axle-tree bands, having bolts passing through them and the brackets. The axle-tree is also secured at each end of the bed by a *yoke-hoop* and *coupling plate;* the hoop can be tightened by screwing up the coupling plate, in case the wood shrinks. The axle-tree beds for iron carriages will be described. The axle-tree arms have a slight inclination downwards termed the *hollow* of the arm, so that the lowest spoke of each wheel may be vertical; if a wheel has no *dish* the *hollow* of the arm is not required. The arm has also a very slight inclination forwards called the *lead;* the hollow and lead together are termed the *set* of the arm. The bearing surfaces of the arms of axle-trees for wheels having cast-iron pipe-boxes are *steeled,* to prevent wear.

Axle-trees are, like wheels, divided into four classes, named respectively *siege, field, general service,* and *naval* service axle-trees; each class contains several natures of axle-tree, but all those in a class have *arms of the same size,* and only differ in the amount of metal between the arms; the similarity in the arms allows of an interchange of wheels when required.

WOODEN CARRIAGES.

Up to a recent date all carriages were of wood, of the form known as block trail, previously they had bracket trails, but they were more clumsy.

There are many wooden carriages both field and siege at present in the service, the Armstrong R.B.L. guns being mounted on them.

The following, a 12-pr., is a type of them all, there are 6-pr., 9-pr., 12-pr., 20-pr., 40-pr. and 64 pr. carriages, also mortar beds of a different construction.

The 12-pr. gun carriage consists of the following principal parts, namely: the trail, two brackets, the axletree, axletree bed, and wheels.

The trail is of oak, usually in one piece, but sometimes in two joined longitudinally; it is fitted with a trail plate with steeled eye for attachment to the limber. The brackets are of oak or elm, attached to the trail by dovetailed housings and by three bolts. The axletree bed of oak is housed both into the trail and brackets, and is secured by axletree bands, which, together with yoke bands and coupling plates, also hold the axle, tree in the bed. The axletree is the field axletree, giving the wheels. which are the O.P. light field, a track of 5 feet 2 inches.

The carriage is fitted with a traversing arrangement, which consists of a metal saddle carrying the gun in trunnion holes, and secured by cap-squares. This saddle slides in dovetailed slots in the trunnion plates, and is traversed by means of an iron lever pivoted upon the trail. The lever is worked by a traversing screw resting in bearings on the brackets, and fitted with a hand wheel. Iron cleats or stops are fixed upon the trail, and allow of $1\frac{1}{2}°$ right or left deflection being given to the gun.

The other fittings of the carriage are a socket or pan for the elevating screw, a chain with hook for securing the gun in travelling, breast chains, trail handles, locking plates, jack plates, and also fittings for carrying side arms, axletree boxes, drag shoe, and small stores.

The articles belonging to the carriage are an elevating screw, side arms, axletree boxes, and a drag shoe with chain. The screw is that known as the "ball and socket" pattern; it is attached to the gun by a bolt and pin, and worked by handles on a wrought-iron collar fixed to a metal nut, which is in the form of a ball.

The axletree boxes are fitted to carry each two rounds of case and some small stores.

The limber for the gun carriage consists of a framework formed by an axletree bed and block of elm, a splinter-bar and three futchells of ash. A platform board of ash, and footboard of elm are secured over the front of the futchells, and a slat of ash to fill the space between the splinter-bar and the footboard. To the back of the block a limber hook is bolted. The axletree and wheels are the same as in the gun carriage, the former being secured in the bed by bolts and by yoke bands with coupling plates. The limber is fitted for draught, for carrying ammunition boxes, entrenching tools, &c.

The articles belonging to the limber are three ammunition boxes, "near," "off," and "centre," with a canvas cartouch for each of the two

first mentioned. The near and off boxes carry each 17 rounds of ammunition.

The ammunition waggon consists of a perch, two sides, and three platform boards of ash, two footboards and an axletree bed of elm, two fluted boards of teak, together with axletree and wheels, the same as in the gun carriage.

The perch and sides, each of the latter strengthened by an iron plate along its outer surface, and the former fitted with a nose plate with steeled eye for attachment to the limber hook, are housed across and bolted to the axletree bed. The axletree is secured in the bed by bolts and by yoke bands with coupling plates. The boards are fitted across the perch and sides, the fluted boards being placed between the platform boards for the ammunition boxes to rest upon.

The waggon is fitted with an axletree arm block of sabicu, shod with iron over the front footboard and front platform board, together with an elm block on the perch for carrying a spare wheel; the fittings for securing the boxes are similar to those on the gun limber.

The articles belonging to the waggon are six ammunition boxes, four canvas cartouches, four under boxes, a drag shoe with chain and spare lashings. The ammunition boxes are identical with those of the gun limber, except the centre are shorter and slightly different shape to the centre box of the limber. The under boxes are one for grease and four for horse shoes.

The waggon limber is the same as the gun limber; it has the letter "W" painted upon it for distinction.

The 9-pr. gun carriage is not fitted with a traversing arrangement.

The carriages, limbers and waggons for the 9-pr. and 20-pr. differ only in details from above, the 20-pr. taking the heavy wheel.

The 6-pr. has a service carriage similar to above, but wheels only 4 feet 2 inches in diameter, track 3 feet 10 inches, the limber and waggon matched, their boxes being different.

It had also a carriage of usual height called Kaffraria, for use in the high grass in those parts.

The 40-pr. and 64-pr carriages are heavier and have two sets of trunnion holes and no axletree boxes, it and its limber have the heavy siege wheels.

IRON AND STEEL CARRIAGES.

(See Morgan's Handbook.)

Iron or steel has taken the place of wood in the construction of all modern carriages, both for field and siege guns.

For field and mountain service there are several natures for the 7-pr.,

2·5 inch, 9-pr., 13-pr. and 16-pr. R. M. L. guns, with their limbers and waggons. Also for the 12-pr. B. L. guns.

For siege guns there are carriages for the 25 and 40-pr., and for the 6·6 inch gun.

The carriage for the 40-pr., with some slight alterations, serves for the 6·3 and 6 6-inch howitzer.

The 8-inch howitzer has a separate carriage; these latter are described in Morgan's Handbook.

Besides these there are various ammunition, forage and store waggons and carts, &c.

We will now describe the latest pattern of the 9-pr. carriage, as a type for the rest.

Mark II. is the latest pattern. It will take either the 6 or 8 cwt. gun. It is formed of two bracket sides, connected by two transoms, two collar bolts, and a trail piece; an axletree bed with axletree, and field wheels of latest pattern, with gun metal naves.

The brackets are formed of iron plate riveted to the inner side of a frame of angle iron of the required form, specially strong at the trunnions.

The transoms are of plate iron. They have angle iron riveted to them, by which they are riveted to sides and bed.

The collar bolts connect the brackets between the transoms and trail their collars keeping it rigid.

The trail piece lies between the brackets at the point, and rivets pass through the whole. This piece ends in an eye, to go on to the limber hook, and is steeled to prevent wearing.

A bearing piece of steel is bolted under the end, and a plate is bolted above to prevent damage, if the limber is driven over it.

The axletree bed is of wrought iron, and forms, with the axle, a beam of box-girder section.

The axletree forms the bottom of the box, a piece of angle iron riveted along each side of the body the sides, while the top is formed by a plate riveted along the upper sides of the angle iron pieces. The whole is fixed into recesses in the brackets, where it is secured by being riveted, to the frames of the latter, by angle iron stays riveted to itself in rear and to the frames, and by tensile stays, from the shoulders of the axletree, to the same.

A strengthening plate is riveted on the inside of each bracket, extending from the bed to the rear transom.

The carriage is fitted with capsquares and keys, metal sockets to

receive the trunnions of the elevating gear, a handspike ring, trail handles, range plate, and a lot of other small fittings.

The elevating screw, which is known as the Whitworth pattern, is attached to the gun in the usual way by a bolt and is worked by a metal nut through which it passes. Bevel teeth are cut upon the lower part of the nut, into which a bevel wheel upon a horizontal spindle gears. The nut and bevel wheel are contained in a wrought-iron box, having a trunnion upon each side, by which it is supported and can oscillate between the brackets. The lid of the box is secured to the bottom by four long screws and has a lubricating hole in it for oiling the bevel wheels through, which hole is filled by a metal screw to keep dust and grit out; a drip hole is made in the bottom and the interior is coated with red lead. The spindle of the bevel wheel passes through a metal bearing or bouch in the trunnion of the box, and upon its extremity outside the right bracket of the carriage has a metal hand wheel, by which it is worked. To remove the box from the carriage the lid has to be taken off, the pin holding the spindle pulled out, and the spindle withdrawn. The second transom of the carriage has then to be removed, after which the bolts of the sockets being taken out, the box with the sockets can be moved to the front, and the former freed from the latter.

The axletree boxes are arranged to carry two rounds of case and small stores. The lid serves as a seat when required. The boxes form seats, with backs and foot rests.

The limber is also chiefly of iron. It is formed of three futchells, a splinter bar with two stays, a platform board, a slat, an axletree bed with limber hook, axletree and wheels.

The splinter bar is of plate iron, bolted to the futchells, and strengthened by a stay of round iron from the extremities to the axletree bed.

The axletree bed is deeper, but of lighter construction than that for the gun. The futchells of the iron are let into the bed, below the top plate.

The limber hook has three long arms, by which it is riveted to and also held at the proper distance from the rear of the bed. It is steeled.

The platform board of ash, and foot board of elm, are placed on top, and fastened to the futchells. The slat is placed in front, between the splinter bar and foot board.

The shafts are the field shafts off and near, of ash. The off shaft has the part between splinter bar and axletree of iron, to give room for the wheel to work, it being fastened for ordinary draught outside the wheel. The limber is fitted for either single, double, treble or bullock draught. The shafts are placed in the centre for single and treble draught, swingle-trees being used in the latter case. A pole is used for bullock draught, fixed in the centre.

The three limber boxes, "off," "near" and "centre," are fastened to the frame by straps. The off and near are similar; each contain 18 projectiles standing in trays, their heads fitting into blocks in the lid The 18 cartridges are in the centre in a canvas cartouch. Four extra projectiles can be carried under the trays, and 4 cartridges in the cartouch. The lids have small stores fitted into straps. The centre box contains fuzes and tubes. Each box has a hand strap for a gunner to hold on by, and outside there are iron guards for the same purpose.

The waggon consists of perch, sides, two platform plates, axletree, &c., as above.

The perch is formed of two brackets, in a somewhat similar manner to the trail of a gun carriage, connected by a perch piece with steeled eye and collar bolts. The brackets are of channel iron, the channel being turned outwards.

The perch lies across the top of the bed, each bracket being rivetted to it by angle iron.

The sides of the waggon are of angle iron resting on the bed, to which they are rivetted. The platform plates are rivetted to perch and sides. The boxes are similar to those of limber.

The limber is identically the same as the gun limber.

The waggon is fitted to carry a spare wheel.

The other limbers and waggons differ only in detail.

The 16-pr. carriage is stronger and wider in the brackets than the 9-pr. The limber and waggon is the same, each box carrying 12 rounds of ammunition.

The 25 and 40-pr. carriages are similar, only stronger.

For description of 13-pr. and the siege carriages see Morgan's Handbook.

The recoil of a 12-pr. B.L. gun is so excessive that means have to be taken to absorb a large portion of it. Experimental carriages with springs, brakes and hydraulic buffers are under trial.

This bed for the 7-pr. of 200 lbs. consists of two brackets of plate iron, secured to a bottom plate; it has a transom in front and angle iron in rear. Upon each bracket there is a handle. It is elevated by quoin. For use the carriage is secured by bolts to a small tee shaped platform.

MOUNTAIN CARRIAGES.

The ordinary carriage is formed of two single plate brackets, strengthened by angle iron along the outside top edge, and secured to axletree by clip plates and bolts. The brackets are connected by two transoms, and trail eye piece.

The elevating arrangement consists of a sliding quoin, worked by a hand wheel and screw. It rests between the brackets, and can be lowered to three separate heights. The wheels are ordinary make, 3 feet in diameter. Check ropes are supplied to fix round trail eye and wheels, to check recoil.

This carriage is similar in height and track to the 9-pr., but of much lighter construction.

The elevating is done by an arc attached to cascable.

The limber, when used, is of light construction, and carries two leather limber boxes.

The Kaffraria pattern is similar to 9-pr., and each box carries 30 rounds.

The Gatling gun carriage is similar in make to the 9-pr., but much lighter, and there is no axletree bed.

The axletree boxes each hold a drum of cartridges, and the lids covered with Bessemer steel, bullet proof, form a protection for the detachment. The limber is as usual, and carries two boxes, protected top and front with steel. One box carries four drums, the other two S. A. ammunition boxes.

The numerous other field and siege carriages of all sorts need not be mentioned here.

STANDING AND SLIDING CARRIAGES, BEDS AND PLATFORMS.

(See Morgan's Handbook.)

The carriages for garrison ordnance have no wheels, and are not therefore adapted to the transport of the guns, for which a separate class of carriages, including sling and platform waggons, &c., is employed. There are three descriptions of garrison carriages, viz.:—

Common standing, Rear chock, Sliding.

The first and last are made both of wood and wrought iron, the rear chock of wood.

The following principles should be observed in the construction of a garrison carriage:—

1. The height of the carriage must depend upon the efficient working of the gun.

2. The carriage must be so constructed that it may be easily run up or back, traversed, or moved from one embrasure to another near it.

3. The carriage should occupy as little space as possible, for it may exposed to enfilade or ricochet fire; and, moreover, it is desirable to all the available space that can be obtained within the battery and

under cover for the conveyance of ordnance, stores, &c., from one part of the works to another.

The material of which the carriage is composed must be capable of withstanding the exposure to the various changes of the atmosphere for a considerable period, as, except when in casemates, the carriages are not under cover.

With guns of over 4 tons, the slope of the platform is not alone sufficient to limit the recoil, and it has been found necessary to check the motion of the carriage by means of a *compressor*, which, by acting against the platform, causes the resistance requisite to absorb the recoil. There are various patterns of compressors.

The *common standing carriages*, when made of wood, are composed of two *brackets*, connected together by a *transom*, two *bolts*, one passing through the transom, and two *wooden ax'etrees*; they are not mounted on wheels, but on small trucks.

Mortars are not, like guns and howitzers, mounted upon carriages, for, being fired at very high angles of elevation, a carriage having wheels or trucks would not be capable of withstanding the shock of the discharge, the vertical strain from which is so very great. *Beds* of wood or iron of simple construction are therefore employed, the whole length of the bed resting on and being supported by the platform. A mortar bed is provided with a quoin, upon which the piece rests, usually at an angle of 45°, and also with bolts on each side, both in front and rear, for the convenience of running the mortar up or back; for siege purposes they have a short trail, and are placed on wheels, for convenience of transport.

CARE OF CARRIAGE.

Wheels should not be allowed to stand in the same position too long, and should often be examined.

Swelling of the wood is certain to mean decay.

The surface may be sound but the rot be underneath.

Any cracks in woodwork should be filled in either by strips of wood if large or by putty.

All carriages should be kept well painted and under cover where possible.

Wooden carriages should be closely examined at each side just behind the brackets, where they may crack.

Small decayed patches must be cut out and all shakes or cracks fille in.

The axles of iron carriages are apt to give just under the brack and the elevating gear sometimes gives way.

When iron is repainted it has to be well scraped if rusty, and washed with turpentine if greasy.

Any *bright iron* of carriages in store must be covered with grease to prevent rust.

When in use axles must be kept well greased and the pipe-boxes free from grit.

CHAPTER III.

ARTILLERY FIRE.

The Principles of Shrapnel Fire especially with Reference to Field Artillery and the 9-pr. R. M. L. Gun.

For many years after the introduction of rifled shrapnel there were many diverse opinions as to the means to be employed to get the best possible results, under the many and various circumstances where it is used.

The chief reason of this diversity being that its action is in many ways very different to that of spherical Shrapnel and of segment shell, and this was not at first understood.

In the former the bursting charge at the moment of opening was never in a definite position as regards the bullets, and, moreover, the angle of descent was usually greater than with a rifled projectile, at the ranges used.

With segment, the charge being in the centre, caused a great spread to be given to the segments, which were of themselves of a bad form for maintaining velocity.

The main purpose of shrapnel is, with a shell of a certain weight, to cover a *given area* with as effective a bullet fire as possible. As an example, a gun firing one round of solid shot at a line extended would but kill one man, whereas a well managed Shrapnel might disable from 19 to 23.

It must be noted that the question of *spread* is very important, as also *power*.

For there is on record a certain shell that gave 121 hits in a very small space, of these only 5 were considered effective, and only 2 men were considered disabled, showing insufficient power and spread.

Suppose a 9-pr. shrapnel be exploded when at rest on level ground, the head and bullets will be found about 35 or 40 yards in front the splinters to right and left about the same distance and the base about 50 yards to the rear.

Any effect then produced by the shrapnel is clearly due simply to the velocity of the shell at the moment of opening, which the bullets and splinters retain, the bullets being by far the most important.

When the shell opens the bullets would continue with the same velocity as the shell and in parallel lines if it were not for:

1st. The disturbing force of the bursting charge.
2nd. The centrifugal force imparted by the rotation of the shell.
3rd. The greater loss of velocity which they experience being smaller and of not such good form as the original shell.

The first cause may be neglected.

When once free the bullets, from the second cause, gradually and regularly spread and form a cone.

The angle of this cone has been calculated and found to agree well with practical experiments.

Now the velocity of rotation practically remains constant, that of translation diminishes with the range, and in consequence the angle of the cone increases as the range increases.

It is probable that the following is about correct:

Under 500 yards	.........7°	2,000 to 2,500 yards	.........10°
500 to 1,300 "	.........8°	2,500 to 2,800 "	.........11°
1,300 to 2,000 "	.........9°	2,800 to 3,000 "	.........12.

With regard to the third cause, although as the distance between the point where Shrapnel are, as a rule, burst and the object is small, it may be practically neglected, still as the bullets begin to drop at once in large distances their fall would be great.

Practically the centre or axis of the cone is but little below the point where the shell would strike; in fact, at 900 yards a shell burst 150 yards short, has the centre of its cone only $1\frac{1}{2}$ feet below the trajectory of the shell; at 2000 yards, and 80 yards short, only 2 feet, and in consequence the drop may be disregarded.

We have to consider with regard to this cone of dispersion—

1st. Its diameter at different parts, for this gives us the *breadth* of front it covers.

2nd. Its *area* at different lengths and the number of bullets and splinters in such area.

3rd. Plan of ground covered by *effective* fire, especially with regard to *length* from *front to rear*, as effecting its action on a *column*.

4th. Effect of height of burst above plane.

5th. *Power* of bullets at different distances from *burst*; when the shell is travelling with different velocities.

From these considerations we find how and where to burst a shell, having regard to the work to be done.

As to *first.* It may be considered near enough to say that for ordinary ranges the cone of dispersion is from 8° to 10°, and the breadth from ·14 to ·17 of its length. Example:—Say a shell is burst at 2,000 yards from a 16-pr. R. M. L. gun 80 yards from the target, at the target its *spread* would be 80 × ·17 = 13·6 yards.

2. The area is, of course, a section of the cone at any point at right angles to the axis, and it is found that the bullets and splinters are fairly evenly distributed over this surface.

As it is known that the number of effective pieces of a 9-pr. Shrapnel are about 85, and of a 16-pr. 136, it is easily to calculate the number that ought to strike an area equal to a man, estimated at 10·5 square feet, at the various distances.

We will find by the following table that, suppose a shell burst at a range of about 1,000 yards and 20 yards in front of a man, the 9-pr. would put 16, and the 16-pr. nearly 25 bullets into him. This is waste of power and shows us the necessity of arranging our bursting point so as to do the most possible damage, one bullet being quite enough as a rule to knock the fight out of a man.

It will be found that a 9-pr. shell if burst at about 1,000 yards would give the following results, its angle of dispersion being about 8°.

LENGTH FROM BURST IN YARDS.

	20	40	60	80	100	120	140	160	180
Front covered (feet)......	8·4	16·8	25·2	33·6	42	50·4	58·8	67·2	75·6
Area of cone, sq. yds.....	6	24	55	98	151	222	302	394	498
No. of pieces, per sq ft...	1·6	·4	·17	·1	0·6	·043	·03	·024	·02
A 16 pr R.M.L. gives.	2·5	·62	·26	·15	·1	·07	·06	·04	·03
A 12 pr. B. L. gives..	4·26	1·07	·46	·25	·17	·12	·08	·06	·04

In practical work many bullets ricochet and are still very effective. This depends upon the distance the burst is from the object, and the nature of the ground.

These have all to be added in practice; they can be, however, easily calculated.

The following table gives a good idea of the result of bursting a shrapnel at various distances in front of a target 6 feet high, at 800 yards, from a 16-pr. field gun:

ACTUAL PRACTICE.

Burst shot.	Area covered. sq. ft.	Direct hits.	Ricochets.	Propn. effective on ricochet.	Men disabled.
50 yds.	126	54	24	1/2	22
100 yds.	252	25	15	1/2	25
150 yds.	378	14	9	1/4	17·4
200 yds.	504	12	2	1/41	10

From these and similar results from the 9-pr. we see that in firing at an extended form it is best to burst about 80 to 100 yards short at a range about 800 yards.

At longer ranges shrapnel must be burst closer, because.

(1.) The velocity and power of the bullets is less.

(2.) The angle of descent is greater, being from $\frac{1}{4}$ to $\frac{1}{3}$ more than angle of ascent, and ricochet less effective in consequence.

(3.) The angle of dispersion is greater, and in consequence we get the same spread without going so far back.

(4.) As the angle of descent is larger the amount of ground covered by the cone is less.

(5.) As the velocity of the bullets becomes smaller they tend to fall proportionately below the trajectory of the shell.

The following distances are about the best for a 9-pr:

	Yds. short.	Front covered.
Under 1,000 yds. range..........	80	33·6 ft.
From 1,000 to 2,000 yds..........	60	27·9 "
From 2,000 to 3,000 yds..........	40	24·8 "
Beyond this....................	30	15·6 "

With the modern 12 B. L. gun its shrapnel may be burst further from the object, for though the spread will be considerable, there are many more bullets distributed over it, and the velocity is much greater.

This valuable power of spreading the effect is peculiar, as will be shown, to shrapnel and *time fuzes.*

The length of ground covered is very important in firing at masses and columns.

A 16-pr. shell, under favourable circumstances, will cover from 410 yards at 1,000 yards range to about 136 at 2,500 yards range, with an effective fire.

It will be seen, from the long narrow elliptical form of the area struck by the bullets (before ricochet) that:—

1st. When the object has depth, the fire cannot be too direct.

2nd. When the object has width and little depth, the more oblique the line of fire the better.

3rd. That time shrapnel is *peculiarly* suited to objects moving towards or from the battery, considerable errors in firing fuzes being compensated for.

EFFECT OF HEIGHT OF BURST ABOVE PLANE

As the drop of the axis is but little below the trajectory, and the greatest spread of bullets is where the central line of the cone cuts the ground line, it is evident that the shell should be laid so as to hit (if blind) a little above the centre of a vertical target.

The circles on the figures clearly show the result of improper height of bursting.

At 1,000 yards a 9-pr. shell ought to be burst 80 yards short and 10 feet above plain.

This varies with every range. Depending on the distance in front it is desirable to burst the shell, that fixing its position in the trajectory.

When a shell bursts too high or too low it may be due to a defective or improperly bored fuze and not to bad laying.

A round or two of shell with percussion fuzes would settle the matter.

DECREASING VELOCITY OF BULLETS.

This is of the most vital importance, and it has been decided that about 400 or 500 feet per second is necessary to disable a man.

Bullets lose in power:

1. As the range increases.

2. When the shell bursts on *graze or after ricochet.*

3. As the point of burst is farther from the object.

4. As more of the hits are ricochets.

As to the first cause it appears that the 16-pr. gave the following results:—

Range.	Strikes and lodges.	Throughs.	Dummies disabled per shell.
800	1	2·7	18·2
1,500	1	1·7	16·1
2,000	1	·46	5·4
3,970	1	·03	1·0

As to the second cause, in a trial with *time versus percussion* fuzes, all of which latter exploded the shells on graze, it was found that the following proportion held:—

	Strikes and lodges.	Throughs.
After graze...........................	4·6	1
Before graze	·675	1

That is, the bullets had, on an average, 7 times the power in one case than in the other.

Third cause—*distance of burst in front.* Taking as before the 800 yards range the proportion of lodges and strikes to throughs are as follows:—

Burst short—yards.		
50......................	1 to 8·56	*i.e.*, diminishing *rapidly.*
100......................	1 to 1·3	
150......................	1 to ·96	
200......................	1 to ·42	

4. As to the power lost by ricochet, it is difficult to estimate it, but as the amount of ricochet increases its power decreases.

Percussion Shrapnel.

Though the actual cone of dispersion is the same with a time or percussion fuze, still the circumstances of the case are very different, for in one the shell opens in the trajectory before graze, and the bullets have a descending angle and a velocity lessened only by the resistance of the air. In the other case it opens after graze and the bullets have an ascending angle and are considerably retarded by the graze.

There is great uncertainty with regard to this angle of ascent, as slight irregularity of ground as to inclination and consistency affects it much.

As a rule the angle of ascent with descending angles under 6° is about one-fourth more. With angles over 6° about one-third more.

It can be seen, if the ground had a slope to the front the angle of descent, on level ground, would be increased and *vice versa.*

The trajectory of a shell after graze is very difficult to estimate, but it is considered that the following is almost correct. The numbers being the height of trajectory, and therefore centre of cone above ground.

Range.	Angle of ascent.	10 yds.	15 yds.	20 yds.	30 yds.	50 yds.	80 yds.	100 yds.	120 yds.
yds.	Degrees.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
1,000	2·55	1·4	2·1	2·8	4·2	6·9	10·6	12·8	14·8
1,300	4·9	1·9	3·00	4·1	6·2	10·1	15·8	19·4	21·1
2,000	5·31	4	5·9	7·8	11·6	19·1	29·6	35·4	38·0
2,300	9·45	5	7·3	9·5	14·2	23·3	....	....	....
2,600	11·40	5·8	8·7	11·5	17·1	28·0	....	....	....
3,000	14·20	6·8	11·2	13·5	20·1	33.0	....	....	....

From this table it is clear that at 1,000 yards, if a shell is burst on graze 50 yards short, the centre of cone passes ·9 feet over the top of a 6-foot target. At 100 yards 6·8 above it.

At 1,300 yards the best time burst is 80 yards short. At figure 4 we see a time and percussion burst at that distance; also one of each burst 120 yards short. The area covered in each speaks for itself.

If both were burst much closer, say 30 yards short at 1,600 yards, the areas would be about the same, but the *spread* is very small and even here; the percussion has practically no ricochet. For the percussion at 30 yards short only covers a front of 9 men, while if burst by time fuze, say 80 yards short, it would cover 20. The percussion at this range would cover less on account of its rise and have no ricochet.

At 2,000 yards a percussion shell 30 yards short would only just touch the top of the target with the very lowest bullets of the cone, and at 40 miss it entirely.

At 2,300 it would just touch at 20, miss at 30. At 2,600 it would miss at 20, and at 3,000 yards at 15 yards short.

There is, of course, no ricochet with percussion shell.

From the above it will be seen how seldom it is desirable to use shrapnel shell with percussion fuzes; if necessary they must be burst on graze very close. The following table shows about the best position and the number of men covered; also the number covered by the same shell if burst as it ought to be by a time fuze. Note the difference.

Range. yds.	Distance. yds.	No. of men covered.	No. of men covered by shrapnel time fuze.
1,000	40	10	24
1,300	25	7	20
1,600	20	5	20
2,000	12	4	20
2,300	10	3	15
2,600	9	3	15
3,000	7	2	15

This necessarily small spread leads to great loss of effect, and also increases the difficulty of making good shooting. Since slight errors in range become very serious, and also small lateral errors; for example, at 1,600 yards the best distance for percussion shell is 20 yards. The spread of cone for this is 8·4 feet, therefore 4 feet to right or left of object half the effect is lost; if 8·4 all is lost. Whereas with a time shrapnel burst where it ought to be the diameter of the cone is 33·5 feet, and a few feet right or left don't matter.

TABLE SHOWING HOW MUCH MORE DIFFICULT IT IS TO MAKE EFFECTIVE SHOOTING WITH PERCUSSION THAN TIME SHRAPNEL.

Percussion Shrapnel.				Time Shrapnel.			
Ranges.	Burst Short.			Ranges.	Burst Short.		
	Effective.	Good.	Bad.		Effective.	Good.	Bad.
Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1000	from 20 to 100	40	over 170	1000	from 10 to 150	100	over 250
1300	" 20 to 70	25	" 145	1300	" 10 to 120	80	" 220
1600	" 15 to 50	20	" 100	1600	" 10 to 110	80	" 190
2000	" 10 to 25	12	" 50	2000	" 10 to 100	80	" 170
2300	" 5 to 15	10	" 30	2300	" 10 to 90	60	" 150
2600	" 5 to 12	9	" 20	2600	" 10 to 85	60	" 135
3000	" 5 to 10	7	" 15	3000	" 10 to 80	60	" 120

A section of a gun pit shows well how much more effective time shrapnel is than percussion. It will also be remembered that with time fuzes the ground in rear is swept by a most destructive fire.

A small rise of ground in front of an object is very prejudicial to the effect of a percussion shell, while it only affects the velocity of a few of the ricochets of a time shell.

One thing is in favour of percussion fuzes, and that is that they are very simple, accurate and reliable; the same cannot even now be said of time fuzes.

1. They cannot be carried fixed.

2. They can seldom be prepared at the limber on account of its distance.

3. If prepared then No. 1 cannot be sure as to how they are bored.

4. The wood fuzes are difficult to bore accurately.

5. Illiterate gunners are confused between seconds of flight and $\frac{1}{10}$ths of fuze.

6. The lighting of the fuze is often irregular.

7. Graze has great affect on them.

However time fuzes on Armstrong's principle have few of these defects.

NATURES OF FIRE.

We will now consider the application of Shrapnel fire to the various requirements of the service.

The objects are men and horses.

The conditions under which the various arms expose themselves differ and in consequence present different targets, so we will take them separately.

ARTILLERY AND CAVALRY.

Cavalry and Artillery when mounted present a considerable height and in consequence the ascending angle of a percussion Shrapnel is less objectionable and in consequence may be more freely used.

Cavalry may expose themselves at long range in large masses without much movement, time fuzes, if available for the range, would be used unless it was found difficult to ascertain the effect.

At ordinary or short ranges Cavalry will be in rapid motion, and unless the ranges have been previously carefully measured and the men can be relied on, percussion fuzes may be permissible from their simplicity and quick service.

Cavalry attempting a sudden flank attack should be received with percussion, for the range is short and the ground must be good for them to be able to advance, and rapidity is all important.

In all cases, however, when a *deliberate* fire can be given time fuzes are best.

Artillery may either have its fire kept down or its mobility destroyed; in one case the men and in the other the horses will be the object.

The old idea of destroying the *matériel* by common shell is impracticable.

If the object is to keep down the fire, time fuzes and frontal fire will be probably best, for the ground behind the guns towards the limbers will be swept and the service of ammunition difficult.

Occasionally oblique fire may enable two or more guns to fall within the cone of dispersion.

If it is desirable to destroy mobility, then *time shrapnel* fire must be kept up on the limbers. It is found practically that percussion fuzes are of little use.

The best chance to cripple a battery is as they are coming into action; and a battery acting on the defensive may often have a chance of making good practice, having previously ascertained the ranges of the likely points of vantage, and having shell with time fuzes ready for that distance, and opening a rapid fire.

If guns are in a pit or behind a knoll, and the limbers retired out of sight down the reverse slope, time shrapnel will hunt them out. The *downward* angle of the cone is the best possible shape, the upward angle of the percussion being useless.

But if the guns themselves and limbers are just beyond the brow of a hill, even percussion would be effective, for its angle of ascent would be small, and sometimes the facing slope is actually safest.

INFANTRY.

As infantry present a low target even when standing up and smaller still when they lie down, percussion shrapnel is very unadvisable.

They will be as a rule in three natures of formation:—

1. Moving slowly at long ranges in large masses.
2. Moving more rapidly in small columns of support at shorter ranges.
3. Moving in short rushes at a sharp double and at close ranges.

In every case there will be pauses when the men lie down and get cover, chiefly, in an attack, of natural obstacles.

1. Common shell has little effect.

If percussion shrapnel is by any chance used, burst at the head or in the column.

Time shrapnel, from their power of covering the whole column from front to rear, should always be used if available.

They should be directed at the *centre* of the column and burst at the distances in front of that point already laid down according to range. It is *not* advisable to *lay* at the head of the column, as much of the cone is wasted in front.

2. and 3. In attacking a more or less extended body of men it is well, if possible, to use oblique fire, so that the cone may range along the line; but even frontal fire, if properly burst, gives excellent result from its spread.

In an attack, batteries placed to flank the ground over which it comes are most effective on the close advance.

The batteries in front would do well to direct their attention as soon as possible to the supports, and leave the infantry to take the advanced line, for the supports form a better object, and if they are demoralized or seriously weakened the line in front will lose heart and retire.

When men are under any natural cover the downward action of time shrapnel is always more effective than that of percussion.

If infantry hold the outskirts of a wood time shrapnel is effective; but if far in the wood, common shell with time fuzes will alone be effective.

Under all circumstances, in a defensive position, it is well to keep a few percussion shrapnel for surprises at close quarters.

Of course if cover is complete and strong, such as houses, walls, palisades, &c., shrapnel of any nature is useless.

Ranges are either—

1. Distant ....Above 3,500 yards.
2. Long.......................From 2,500 to 3,500.
3. Ordinary....................... " 1,200 to 2,500.
4. Short....................... " 800 to 1,200.
5. Close.......................Under 800.

1. Range is limited, 1st, by the distance at which the shell ceases to have sufficient power; 2ndly, by the distance at which the eye, even when assisted, is able to ascertain the accuracy of the practice and its results.

The absolute necessity for correct observation limits the length of range, except under very special circumstances, long before the actual extreme power of the gun is reached.

Accuracy is the first essential, especially at long ranges, where the ground covered by the shell diminishes.

Range finders are of great assistance, but actual observation is necessary to correct errors.

Range tables being formed from practice under the most favorable circumstances are only approximately correct.

The distance at which effect can be judged with certainty is limited by—

1st. The actual distance.

2nd. Atmospheric conditions, as fog or haze, smoke, sun, twilight, &c.

3rd. Direction of the light.

4th. Ground on which the object stands.

5th. Amount of smoke from burst of shell.

6th. A number of batteries in action at once confuse results.

The third is little suspected, but is very important.

The effect of shrapnel can only be judged by constant practice; it is easier with percussion than time shrapnel, as they burst on the ground.

At practice a shrapnel was judged by several observers as "over," yet it was 120 yards short, range only 1,100 yards.

Distant fire may be necessary under the following circumstances:—

a. When in a reconnaissance it is desirable to make enemy disclose his strength or position.

b. Against such an attempt when exposure does not matter.

c. When acting as a retaining force, to force enemy to deploy.

d. In defensive positions, when enemy shows himself in large masses.

e. When fire has to be concentrated on an important point from an extended line of batteries.

f. In a pursuit, if an opportunity offers itself to shell a narrow defile, or if it is impossible to get closer.

g. In retreat it is advisable to keep the batteries engaged as long as possible and out of the road.

When the enemy can easily and quickly move his position, like a regiment of cavalry, every precaution being taken, salvos should be fired and shells kept in readiness at the guns to keep up a rapid fire.

If range has not been ascertained it must be got as soon as possible with common shell and quickly followed by shrapnel and time fuzes, which now can be burst every $\frac{1}{4}$ second up to 30 seconds.

The great loss of power and effect which shrapnel suffers from increase of range makes it a matter of judgment, with the O. C. Battery as to its use. It must be remembered, however, that the power of

shrapnel from the now high velocity guns has enormously increased, the velocity of a 12-pr. at 7,000 yards being 500 feet per second, and at 3,000 being greater than the 16-pr. shell at 2,400 by 27 feet per second.

In consequence, under favourable circumstances of vision, shrapnel may be more freely used from these modern guns or with heavier natures of guns when available, for their bullets are heavier and carry farther.

Many practical artillerists maintain that field shrapnel ought seldom, if ever, to be used over 2,000 yards.

2. At long ranges the difficulties are not so great; it is easier to make good practice and to estimate results.

It still is difficult to make good practice at moving objects.

Above all it is necessary to ascertain the range of well-defined objects, and due allowance must be made for time of flight and rate of moving objects.

3. At ordinary ranges, unless time is an object, it is always well to verify range finders by a round or two of common shell and percussion fuzes, especially when the object to be fired at is small, as a gun in a pit. Remember, however, that the shrapnel is, as a rule, slightly heavier than common shell, and that it is desirable to have its cone of dispersion at best advantage; therefore, the trajectory should be slightly above that of a common shell.

Therefore a few minutes more elevation ought to be given.

At ordinary and short ranges time fuzes are the best, but often, in the case of a sudden attack, time is so important that percussion fuzes may be used, as they are easier to manage, especially if the battery is short-handed or the men flurried; besides, the nature of the ground is not of so much importance, and the angle of descent, and therefore of ascent, is very low.

At close ranges no doubt percussion fuzes are best till case can be used.

Reversed shrapnel are of little value.

CHAPTER IV.

SIEGE ARTILLERY FIRE.

When it has been determined to reduce a fortress by a regular siege, the strength and composition of the siege train, the position of the batteries, and the probable quantities of ammunition that will be required for each piece, must be at once decided.

The composition of the train will depend upon the strength of the place, the position and nature of the works to be attacked, and the means that are available for transportation.

It should be remembered that by employing accurate pieces of ordnance with large shell power there will be a great saving in time and material employed; hence always use the most powerful pieces appropriate to the work that are available.

The amount of ammunition depends upon the nature of work to be done and the amount of opposition to be expected.

At the early parts of a siege the fire is usually as rapid as is consistent with accuracy, in order to if possible establish a superiority over the defence, at least 200 rounds per day being used. After this the fire becomes much more deliberate, but a total of at least 1,000 rounds will be required for each important piece.

The choice of base and fronts to be attacked and the actual position of the various batteries is arranged by the superior officers in consultation, and hardly come within the scope of these notes.

The artillery parks would be close to the best line of communication, as well concealed as possible, and from 6,000 to 7,000 yards from the most advanced works.

The main magazines being about 8,000 yards away.

Beside the general park there would be intermediate depôts, which should be connected, if possible, by rail with the general park and with the batteries they are to supply. These depôts should always have sufficient ammunition for 24 hours' use.

There are many points to be attended to in arranging the main park and magazines, the utmost order being observed and all regulations most carefully carried out.

Magazines should not be too large and should be well separated, and, if possible, lofty and solid banks of earth should separate them.

Each pile of projectiles should be clearly marked and protected as much as possible from weather.

The actual nature of siege batteries is described in the Fortification course.

They depend greatly on the nature of the ground and would be naturally or artificially screened.

They are either elevated or sunken, the latter being preferred because they are more easily screened, affords more cover, can be easily and quickly executed with a comparatively small amount of material, and a large amount of undisturbed soil is utilized in its construction. They are often difficult to drain, and sometimes in rocky ground are impossible.

A loose, sandy soil resists a continuous fire far better than a tenacious clay.

The experiments of late years at Lydd were chiefly at parapets of a

clayey soil, and it has been since ascertained that the results are not in some cases reliable; in fact, high velocity shells seem to rise out of sand as they do out of water and to take but little hold of it.

PLATFORMS OF SOLID CONSTRUCTION ARE LAID.

Platforms are either Clerk's (strengthened) or double decked wooden ground siege platforms.

The former is laid so that the line of fire passes down its centre, the side pieces can be slightly moved to allow for slight traversing.

There are two methods of laying them and they are available for the 25-pr., 40-pr. and 6·3-inch Howitzer.

Double decked platforms are necessary for the larger natures of Howitzers, they consist of two layers of planks on transverse planks.

Wheel guides and wheel plates are used in connection with them, the former to guide the gun on running up into the line of fire, so as to be in right position as regards the anchorage and to simplify the reverse laying.

Steel wheel plates are to prevent injury to the ptatform, for which purpose trail planks are also used.

As the wheels and trail are on metal surfaces, there is often a movement of the trail after the gun is laid, this may be overcome by sprinkling sand on the steel plate.

The anchorage for hydraulic buffer is described in Morgan's book.

There are two well-defined artillery positions, the first or distant, and the second or nearer of the two.

The various considerations which determine their positions and distance will not be considered here, but those of the first position would probably be from 2500 to 3000 yds. from the permanent works of the Fortress.

Under favourable circumstances this distance might be reduced.

ARMANENT AND DIFFERENT NATURES OF FIRE APPLICABLE TO BATTERIES OF THE FIRST ARTILLERY POSITION

The various natures likely to be employed from the first artillery position are as follows:

a. Fire against visible works or armament.

b. Fire for enfilading long and probably strongly traversed faces.

c. The fire of howitzers for searching effect.

d. The high angle fire of howitzers to destroy overhead cover or buildings.

e. The shrapnel fire of howitzers for searching effect.

f. The shrapnel fire of howitzers and guns by night to hinder the enemy making good damages.

When not otherwise stated common shell with direct action, or similar fuzes, are supposed to be used.

It is probable that a combination of light and heavy ordnance would be used.

Combined accuracy and shell power is necessary in the ordnance used in these long range batteries, therefore at ranges beyond from 1200 to 1600 yards, the lighter guns and howitzers would not be used except for a general bombardment.

We have then available the 8-inch howitzer of 70-cwt., the 6·6 inch gun of 70-cwt. and the 6·6 inch howitzer of 36-cwt, the latter being the least accurate.

a. The accuracy and shell power of the 8-inch howitzer render it the most formidable piece against visible works or armament, as with maximum charges the parapet is soon cut down and the carriages, &c., exposed, and in consequence easily destroyed far more completely than by a chance shot from a gun.

The 6 6 inch gun being more powerful and having greater accuracy would be better than the 6·6 howitzer of like shell power.

b. The same order holds good in this case, and it must be remembered that the angles of descent from guns are small, even at long ranges, and in consequence they are not good for this nature of fire.

c. The searching effect of common shell is very small indeed, and the effect of the later patterns of shrapnel with large bursting charges is much greater.

d. High angle fire with howitzers is a great matter of chance, as it is not possible to ascertain the exact position of the enemy's magazines, casemates, &c., and it is difficult to judge of effect.

e. The high angle fire of either the 8-inch or 6·6-inch howitzers would be very effective in clearing out the enemy's gun detachments.

g. At night it might be continued, aided by the direct shrapnel fire of guns, at the most likely points where the enemy would be making repairs.

ARMAMENT AND DIFFERENT NATURES OF FIRE APPLICABLE TO BATTERIES OF THE SECOND ARTILLERY POSITION.

The second position is much nearer the fortress, and the batteries are intended to deal more in detail with the fronts attacked, one face being enfiladed, another counter-battered, and so on; other batteries being used for breaching.

The general object of these batteries is to prepare for the close attack, for which purpose it is necessary—

a. To silence the artillery fire of the place. This can be temporarily done by the searching fire of howitzers, but it is necessary to silence the guns permanently by dismantling them, either by frontal, oblique or enfilade fire.

Frontal fire is best used if the guns are mounted behind embrasures, for though the mark is small many shot are deflected inwards from the sides of the embrasure.

In most cases the guns will be mounted on overbank or disappearing carriages, and are more difficult of access.

Little or no effect is produced by a direct hit, unless on muzzle or trunnion; therefore frontal fire is not to be desirable. If, however, it is necessary, the large shells of howitzers or the largest guns directed at the parapet will be most effective, as they lay open the emplacement as well as dismount the gun.

At Dungeness an earthen parapet, 30 feet thick, exclusive of slopes, was breached in 7 rounds, 6 of which were effective, from the 8-inch howitzers of 70 cwt., at 1,200 yards.

When using guns for oblique fire there is a larger target to hit; but if it is desirable to breach the parapet as before, the difficulties are increased by the extra amount of earth to lift.

We see, then, that if we are obliged to use guns of small shell power for dismounting, oblique fire and direct hits is the best, but with guns of large power or howitzers then cut down the parapet by frontal fire rather than oblique.

For enfilade fire at the comparatively short ranges of these batteries, curved fire from howitzers would alone give a large enough angle of descent, and as the traverses would be formidable the largest natures of howitzers would be required if they could be spared from the important operation of breaching.

b. The second object is to open up such of the enemy's works as more especially bear on the attack and so prevent their re-armament or occupation for small-arm fire.

Here again the greater the shell power the sooner the object is effected.

c. Next we want to dislodge any field or machine guns that may be established to annoy and retard the works of the attack.

If these pieces are only covered by slight works, the lighter siege guns may be used, but if strongly posted they must be treated as before mentioned.

d. To breach escarps or detached walls.

Here the angle of descent as a rule has to be large, howitzers must be used, and as powerful a nature as possible.

e. To silence if possible flank defences bearing on the attack

In this case, it is often necessary to bring up some of the lighter siege pieces into the advanced works of the attack, when curved fire of howitzers or the direct fire of guns will be used as necessary.

f. To prevent repairs or removal of debris.

For this a steady and maintained searching fire with common and shrapnel fire from howitzers must be kept up to annoy the working parties; shrapnel is best for night work.

g. To cut down interior retrenchments and disperse masses of men collected to repell an assault of a breach.

For this purpose a heavy fire of common and shrapnel shell from howitzers would be best, arranging various angles of descent so that the whole area covered may be well searched out.

From what has been said it is evident that howitzers' firing large common shell are by far the most important part of the siege train, for they have great power and fair accuracy and comprise very varied angles of descent.

The heavier guns as stated can be employed in assisting in the destruction of exposed works and the lighter guns to destroy light cover and sweep the line of approach of sorties.

Iron defences when they exist can only be dealt with by powerful armour piercing guns, such as the lighter of the modern R L. guns.

THE AMMUNITION USED IN THE SIEGE TRAIN.

PROJECTILES.

The following projectiles are employed in the attack of fortresses viz.:—

Common shell.
Shrapnel shell.
Star shell.
Case shot.
Battering shot.

The common shell is the most important. It is to be used with fuzes of the nature of the direct action fuze, which, though quick, are not absolutely instantaneous, and allow considerable penetration before bursting.

The direct action fuze will not act on graze with certainty at angles of descent less than 10°.

The R. L. fuzes cannot be used from howitzers, as the shock of discharge is not sufficient to prepare them for action.

When common shell is used for destroying overhead cover a delay action fuze ought to be used or a time fuze bored long.

Fuzes for the siege train are at present in a transient state.

Common shell fire is effective against earthwork or masonry at any distance within the effective range of the piece.

Battering shot must be used from high velocity guns against iron defences, and possibly with advantage against granite, but for ordinary brickwork or concrete it is found that common shell practically penetrate as far and their bursting charges are larger.

The effect of shrapnel from siege guns is similar to that from field guns, but it must be remembered that the heavier shell keep their velocity better, and the size of the bullets are greater, varying from hardened lead bullets of 20 to the lb. in the 25-pr. to the 14 to the lb. in the 8-inch howitzer, their number is also much greater.

With the guns, therefore, a greater long limit of effective burst is allowable.

With the howitzers the velocities are low, and so each case must be taken on its merits, and an effective fire can only be maintained by an intelligent application of a thorough knowledge of the effects of shrapnel fire. This has been very thoroughly gone into in the case of field shrapnel.

Time fuzes must be of a special nature or specially prepared to ignite with the low charges of howitzers.

Star shells are used to illuminate the enemy's works; they are effective up to 1,200 yards.

They ought to be burst from 100 to 200 feet up in the air, in rear of and to windward of the spot to be illuminated.

They are useless if they fall short or to leeward, as it is necessary that the illuminated smoke form a back-ground.

Case shot would only be used to repel sorties and from guns specially placed in advantageous positions for the purpose.

They could only be used for direct fire.

CHARGES.

With guns full charges would always be used; with howitzers maximum charges would be employed for—

a. Distant bombardment.

b. The destruction of visible works or armament.

c. In cases of curved fire, where the resulting angle of descent is large enough for the purpose required.

For high angle fire and for curved fire for the destruction of concealed revetments, walls, or obstructions, the charge has to be varied so as to give the necessary angle of descent from the particular battery and piece.

The cartridges would be invariably supplied in metal-lined cases.

The various methods of laying are treated of in the Artillery Manual; of these, reverse laying by means of French's sights is the most important, being equally effective and accurate by night or day.

All howitzers have 2 sets of French's sights. Guns have one set French's and one set ordinary. When not in use they should be kept in a place of safty.

It must be remembered that in the case of howitzers, when the time of flight differs for a certain range for each charge, and when in consequence the drift is different, there is no permanent slope given the sights; they are upright; and the necessary left deflection is to be ascertained from the tables and given on the sight.

For example, with the 8-inch howitzer of 70 cwt. at 1,500 yards range, and with its maximum charge of 11½ lbs., the drift sight is 3·3 yards, and the necessary correction is 8 minutes left deflection.

With its smaller charge of 3½ lbs. its drift is 19 yards and the necessary deflection is 43 minutes.

With guns the sights have the necessary deflection for their full charge.

It has been noted that guns that have been sighted for *studded* projectiles shoot to the left if used with smooth studless projectiles, and allowance will have to be made, the drift not being so great as in the first case.

In giving elevation by the clinometer great care should be taken to insure the instrument being correctly set by the graduated scale, that it is placed in the same position every round, and that the air bubble is exactly in the centre of the tube, always finishing with depression.

Before opening fire from a battery it is advisable—

a. To ascertain the range from a mean of several observations with a range finder.

b. To be sure that all arrangements in the battery are complete.

c. To decide on the best point of burst or impact and to arrange for an observation party in direct communication with the battery to signal each round, as by this means alone can a steady fire be maintained.

Accuracy should never be sacrificed for speed, though they are often combined.

Ammunition is to be economized. Never fire a shot till the results of the previous one have been considered and the necessary corrections made.

Wet sponges ought not to be used with howitzers using small charges.

Be sure the charge is correct and the projectile rammed home each time, and the staves of the rammers being carefully marked for this purpose.

Stability of platform, especially under the point of the trail, is very important.

Economize labour as much as possible—

a. By getting sufficient recoil and not too much.

b. By securing trail plates so as not to require constant adjustment,

c. Elevate a little before ramming home.

d. Place a few sand-bags or pieces of skidding for the muzzle numbers to stand on when lifting the projectile.

Hurters and wheel guides should only be placed after the gun is in the line of fire, for the platform may not be parallel to it, and in consequence the hurters may be best when not at right angles to its axis.

If a tube misses fire, after a time, prick the cartridge, as there is probably a seam in the way.

Should a shell jam in the bore withdraw it if possible, remembering to replace the cap of a D.A. percussion fuze before lifting it out of the gun.

If the gas check is jammed ram it strongly home separately.

Perhaps the bore wants cleaning.

If the shell cannot be withdrawn rig rammer ropes to the stave, and by carefully manning these ram home all together.

If this is impossible fire the gun, remembering that the projectile will fall short. If this is apt to cause danger to your own side, the charge must be drowned and the shell blown out with a little F.G. powder.

In conducting the fire of howitzers, when the charge is small, the elevation high, the velocity low, and the time of flight long, it is useless to attempt to correct the fire by altering every round. Get a shot over and a shot under, take half the difference, fire several rounds, note mean point of impact and correct if necessary, making decided changes in the first rounds and afterwards if necessary.

The same process would be best for howitzers with heavier charges, but the alterations necessary are smaller.

EXAMPLE (8-INCH HOWITZER, 70 CWT., CHARGE $3\frac{1}{2}$ LBS.)

1st round.—Elevation due to 1,000 yards = 13° 10′ observed under.

2nd round.—Elevation due to 1,110 yards = 14° 48′ observed over.

Half the difference in elevation is 49′.

3rd and following rounds—14°, to be further altered if necessary.

Howitzers when heated from rapid fire give a slight increase of range and must be allowed for.

A careful report has to be made from every battery at the termination of each day's firing, of the amount of ammunition expended and remaining on hand, for the information of the officer in charge of the artillery park.

FIRE UNDER VARIOUS CIRCUMSTANCES AND FOR VARIOUS PURPOSES.

Against Exposed Earthen Parapets.

The object is to cut a breach through the parapet and open up the interior. To do this, place the first few rounds well down on the exterior slope, and as the breach progresses the elevation must be gradually increased. The greater the angle of descent the greater the difference in elevation. (See figures.)

With flat trajectory guns at short ranges but little difference is required.

When firing at very long range the sole object will be to hit the parapet, the exact point being uncertain.

FIRE TO ENFILADE STRONGLY TRAVERSED FACES.

It is generally best to first breach the parapot that screens the view, in order to note the point of impact on the traverses as they are fired at. With very long range no particular point of impact can be assured.

FIRE AGAINTT VISIBLE ARMAMENT.

It is best to open up the works with heavy shell fire. Direct hits are seldom effective and the target is small. If guns of small shell power are to be used they should have their line of fire inclined about 45°, as this gives a larger mark.

FIRE OF HOWITZERS FOR SEARCHING EFFECT.

Fire first a few common shell of the same weight as the shrapnel; their flash is large and the exact elevation is soon found, so that the trajectory would pass through the proper point.

The fire is then continued with shrapnel, burst pretty close to the object, for the velocity is not very great and the area to be swept is small, and there is a good deal to be done in it.

FIRE AGAINST SCREENED OR CONCEALED BATTERIES.

The supplementary extemporized outworks of a fortress are frequently of the same form and nature as those of the attack, and, like them, screened or concealed.

The distance they are behind the screen is as a rule unknown, and the point of impact cannot be seen.

If possible ascertain the range by measuring carefully a base and making simultaneous observations from the two ends of the smoke from a gun.

If possible the screen must be cut down; but if it is a natural undulation of ground, this is impossible, and the practice must be very uncertain. An observer with a straight edge laid on the smoke of a gun could signal whether a shot was over or under.

FIRE FOR BREACHING.

There are two cases:

a. Breaching escarps surmounted by earthen parapets.

b. Breaching detached walls.

The conditions of fire as to angle of descent and velocity attainable for any particular case are to be estimated, and fire opened and conducted as follows:

Having settled the conditions of fire for the purpose required, as will be explained hereafter, and the breaching batteries established and armed accordingly, fire will be conducted as follows:

a. First, in breaching escarps, the most effective place for the mean point of impact is about a fourth of the height of the wall, below the top. The lower projectiles of the series will strike to about half way down the wall, and the upper ones up to the cordon.

A group of rounds is first fired and the elevation corrected, if necessary, until it is found that half the shots strike short of the crest of the glacis and half clear it, then by adding minutes of elevation corresponding to a fourth the height of the wall, or to whatever height it may be deemed necessary.

Suitable posts of observation must be formed, and the results of each shot communicated to the battery, and stating whether the projectile strikes the glacis, the wall or the parapet.

The sliding down of the earth as the wall is destroyed gives an idea of the width of the breach forming, and which may be increased by giving deflection.

As a rule breaches should not be formed till the advanced works of the attack reach the glacis, when accurate observations can be made.

b. Breaching detached walls is more difficult, because the angle of descent must be greater, the wall being nearer the counterscarp and having to be destroyed to within about 3 feet of the ground; also, there is not such a good chance of estimating the effect of the fire.

In conducting fire for this purpose, select the crest of the glacis as mean point of impact, then as it becomes cut down the projectiles will take effect lower down on the wall.

Observations from the crest of the glacis can alone determine extent of damage

FORMATION OF BREACHES.

Modern works with narrow and deep ditches, with well covered escarps and detached walls, have much increased the difficulties of a siege. Angles of descent of 20° or more are sometimes necessary.

The old system of breaching by forming horizontal and vertical cuts of short range is no longer practicable.

Breaching by "demolition," *i.e.*, by destroying the revetment by a fire distributed over the portion of the wall to be breached must be employed.

In breaching escarps, surmounted by an earthen parapet, it will be necessary to destroy the wall half way down, measured from the cordon; and in the case of detached walls, to destroy the wall within 3 feet of the ground.

The profile of the works to be attacked would generally be known, we require to know,

a. The height AB of the wall to be breached.

b. The relative levels of the top of the wall and the crest of the glacis.

c. The horizontal distance between the face of the wall and the crest of the glacis.

When the above are known the least angle of descent necessary to strike half way up the wall can be calculated.

Subtract half the height of the wall from the height of the crest of glacis above bottom of ditch, let this = AB. Let BC be the horizontal distance between the wall and the crest, then we obtain the angle from $\tan. ACB = \frac{AB}{BC}$.

This can also be measured from a careful drawing to scale.

The angle formed is then looked for in the range tables for the piece in question and the most suitable charge selected for that range.

The extra elevation is easily found to raise the point of impact to at fourth of the height as before mentioned.

We must next consider what howitzers are available, and the lowest striking velocity, also the greatest obliquity of fire permissible, in each case with due regard to effect.

It must be remembered that the greater the range the greater the striking velocity with a given angle of descent; but the greater the range, the more inaccurate the fire and the greater the difficulty of observing the effect.

Again, the more oblique the position of the battery to the face to be breached, the lower down it can be struck with a given striking velocity; but the greater the obliquity of fire, the smaller the effect, especially at first and the greater the thickness of masonry to be pierced.

LOWEST EFFECTIVE STRIKING VELOCITY.

It must be borne in mind that when high angles of descent are required the actual effect of a shell is much reduced, as the horizontal component of the striking velocity becomes smaller as the angle increases, while at the same time smaller and smaller charges are being used.

It is considered that with the 6·3-inch howitzer it is desirable to secure a striking velocity not much below 400 F.S.

With the charges used with the 6·6-inch R.M.L. howitzer, the smallest, *i.e.*, 1 lb. never gives a less velocity than 420 F.S., which is effective especially against detached walls.

With the 8-inch howitzer of 70 cwt., the smallest charge is 3½ lbs., which gives 432 F.S. at 1,500 yards, and is consequently effective at all ranges. As the velocity of 400 F.S. is considered effective with the smallest of these howitzers, it is much more so with the largest firing a shell of 180 lbs, against the 70 lbs. common shell of the 6·3 inch howitzer.

GREATEST OBLIQUITY FIRE PREMISSIBLE WITH DUE REGARD TO EFFECT.

When works are attacked having such narrow and deep ditches that, if frontal fire be used, the angle of descent necessary to strike low enough would reduce the striking velocity too much, we must have recourse to oblique fire, in this way we increase the horizontal balance between the point to be struck and the crest of glacis, and can use a smaller angle of descent.

Generally speaking, the heavier the shell and the greater the striking velocity, the more oblique may the angle of impact be to produce a given effect.

From experiments, it appears that with the 6·3-inch howitzer effective results were produced with the 70-lb. shell and 400 F.S. velocity at an angle of as great as 60°.

With the 6·6-inch with 100-lb. shell and 482 F.S. velocity, a fair effect is produced on granite up to 45°, only more shell may glance.

With the 8-inch and a 180 lb. shell, good effects were obtained with angles of 40° and 45° and velocities of 650 and 450 F.S. respectively.

RANGE TABLES FOR R. M. L. HOWITZER OF 70 CWT.

PROJECTILES, COMMON AND SHRAPNEL SHELLS, ROTATING GAS CHECKS, WEIGHT 180 LBS.

Range.	Drift right.	Elevation.	Deflection left.	Angle of descent.	Remaining velocity.	Five minutes elevation increases or decreases range by	Five minutes will alter point of impact vertically or laterally at each range.	50 per cent. of rounds should fall within Length.	Breadth.	Height.	Time of flight.	Fuze scale.	Charge R. L. G₂.	Muzzle velocity.
yds.	yds.	° ′	° ′	° ′	f. s.	yds.	yds.	yds.	yds.	yds.	secds.		lbs.	f. s.
1500	3·3	4·45	0.8	5·12	858	23·8	2·18	20·1	·52	1·84	5·1	As the time fuze is graduated to ¼ seconds, simply double the time of flight to get the graduation.	11½	956
6300	**144·0**	**30·24**	**1·18**	**44·24**	**710**	**8·9**	**9·16**	**66·4**	**8·35**	**?**	**27·9**			
1500	3·8	5·24	0·9	5·54	829	26·8	2·18	19·1	·57	1·98	5·2		10½	920
5900	**122·5**	**30·36**	**1·11**	**41·57**	**680**	**8·3**	**8·58**	**62·0**	**7·27**	**?**	**27·7**			
1500	4·8	6·6	0·11	6·48	792	18·5	2·18	18·1	·65	2·19	5·4		9½	875
5600	**111·0**	**30·24**	**1·8**	**39·24**	**643**	**10·4**	**8·14**	**55·6**	**6·55**	**?**	**28·2**			
1500	6·0	6·56	0·14	7·48	749	15·6	2·18	17·1	·72	2·38	5·4		8½	825
4600	**74·0**	**29·42**	**0·56**	**37·9**	**641**	**8·3**	**6·69**	**45·1**	**4·41**	**?**	**23·2**			
1500	7·7	8·12	0·18	9·3	700	13·9	2·18	16·2	·79	2·49	5·7		7½	770
4300	**74·0**	**30·24**	**1·00**	**36·46**	**603**	**7·8**	**6·25**	**40·0**	**4·21**	**?**	**23·5**			
1500	9·2	8·52	0·21	9·54	650	12·5	2·18	15·4	·88	2·70	6·1		7	715
3900	**68·0**	**30·24**	**1·00**	**38·30**	**590**	**5·8**	**5·67**	**36·0**	**3·52**	**?**	**21·5**			
1500	9·8	9·42	0·22	10·42	648	11·9	2·18	14·6	·98	2·76	6·3		6½	710
3600	**60·3**	**29·36**	**·58**	**35·24**	**581**	**5·2**	**5·23**	**31·4**	**3·09**	**?**	**20·2**			
1500	13·2	11·54	0·30	13·12	582	9·2	2·18	13·0	1·11	3·06	7·3		5½	641
3000	**50·2**	**29·0**	**0·58**	**36·42**	**561**	**4·6**	**4·36**	**24·1**	**2·44**	**18·10**	**17·1**			
1500	18·3	15·30	0·42	16·54	507	6·4	2·18	11·4	1·26	3·45	8·8		4½	556
2400	**51·4**	**28·56**	**1·14**	**33·12**	**486**	**4·7**	**3·49**	**17·5**	**2·07**	**11·50**	**16·2**			
1500	19·0	22·15	0·43	23·30	432	4·0	2·18	28·1	2·00	12·3	10·9		3½	473
1900	**42·2**	**32·24**	**1·16**	**37·37**	**436**	**2·1**	**2·76**	**38·2**	**2·80**	**29·4**	**14·9**			

POSITION FOR BREACHING BATTERIES.

Breaching batteries would be about 1,500 yards from the work to be attacked, and it is found that we can get from our howitzers, at about that range, angles of descent large enough for the requirements of modern fortresses, and at the same time effective striking velocity.

If the batteries are a little nearer the angle of descent, with the same charges and therefore velocity, will be slightly increased, and the contrary if a little more distant.

In placing the batteries, it must be remembered that though the greater the velocity the greater the penetration, accuracy and effect of individual projectiles, the lower down the wall or escarp is destroyed the more complete is the destruction, and the more difficult its repair.

We, therefore, consider that it is best to employ rather larger angles of descent than may be theoretically sufficient to form a breach if left undisturbed by the besieged.

Curved fire being now so accurate, it would be seldom necessary to form batteries close up to the fortress for breaching purpose, but a few light pieces might require to be placed in the advanced works after the breach is made to destroy flank defences, &c.

In order to keep a breach open when formed, an accurate searching fire must be kept up by day and night, and the angles of descent considerably greater than are necessary for breaching.

The shrapnel fire of howitzers with angles of descent up to 25°, and the shell burst at about the crest of the glacis will be most effective, the accuracy of the fire should first be assured by day.

Immediately before the assault a fire of common shell must be opened to clear the breach of obstacles that may have been placed there.

ATTACK OF IRON DEFENCES.

For the attack of wrought iron defences, which may be expected in future sieges, nothing but the fire of powerful armour piercing guns will be of any use.

It would be necessary to employ powerful siege guns that might be transported in several parts on the pattern of the 2·5-inch Mountain gun, or such a gun as the 6-inch B.L. gun of 89 cwt. might be employed.

Chilled cast iron shields and armour on Grüson's construction is being much experimented on in Europe, and it is found that the most powerful guns in existence have but little effect on it.

Turrets and shields of this material can be easily constructed, for the plates or rather blocks used can be cast, with little expense for plant, in the immediate neighborhood of the work being built.

These shields smash up the hardest Palliser projectile, and the finest

steel forgings. They are in section something like the section of a Palliser shell, no ordnance possible to employ in the siege train would appear to have any effect on them.

OBSERVATION OF THE EFFECT OF FIRE.

The effect of every round must be carefully noted.

Experience alone can afford reliable conclusions.

Ports of observation must be established and good telescopes and field glasses used.

The main point is to be able to see the object fired at, or to be able to note circumstances that will enable us to judge of the effect, although the object is invisible. This applies especially to breaching where though the point of impact is invisible, the effect is easily estimated from the appearances.

The difficulty of observation increases with the ranges. In the second artillery position, points of observation in the immediate neighborhood of the battery will suffice, but in the case of batteries in the first artillery position outlying posts of observation, if possible in telephonic communication with the battery, are necessary, and every shot must be signalled from them to the battery.

In the case of screened or concealed batteries, the posts of observation, when near, ought to be on the screen or crest of the undulation concealing the battery, but slightly to the flank, and be themselves carefully concealed.

If these posts are too much to a flank, a shot that falls short, but to the same flank, may seem of correct range. and *vice versa.*

When the battery to be attacked is itself screened, it is extremely difficult to ascertain. what is being done, though observations may be sometimes made from the flanks or open natural or artificially elevated posts, the latter, however, would be open to the enemy's fire.

APPEARANCE OF BURSTING SHELLS IN BREACHING FIRE.

At any range at which breaching is likely to take place the shell from a howitzer is visible throughout its entire trajectory.

The following appearances are observable in breaching when directed against a concealed wall, and indicate the point of impact :—

1. Shell short on glacis ; the flash and the earth shot away on either side are distinctly visible. and the work behind will be seen partially concealed by the smoke.

2. Shell over—in earthen parapet ; flash of burst faintly seen ; much more earth displaced than in first case, and the smoke will be observed hanging in the crater for a considerable time.

3. Shell struck the escarp high up; flash not seen (but reflection visible as smoke in dark); the smoke appears at once globular in form, the lower part alone being hidden from view; fragments of masonry thrown up, and a red or grey cloud of dust will be usually observed from the brick or concrete.

4. Shell struck escarp low down; flash not seen (except its reflection after dusk); smoke longer in appearing than in the last case and seems to be flattened out against the wall; fragments of masonry and dust as before.

In firing at detached walls as a rule the appearances are the same as above, except that those shells that pass through holes already made are apt to mislead, as they strike the earthen parapet and seems to be over.

CHAPTER V.

MANUFACTURE OF STEEL.

The steel used in the construction of ordnance is invariably that commonly known as "cast steel." In fact, according to the modern scientific nomenclature, it is only steel proper that is used, and not what may be known *in trade* as "steel."

"Steel" only differs from "wrought iron" in *structure* and mode of manufacture.

Steel is obtained in various ways, by more or less decarburetting cast iron under such conditions as to obtain a *melted product*.

The old method, which is still employed for the finer natures of steel, is a very roundabout one. The cast iron having most of its carbon burnt out in the process of "puddling" and being formed into wrought iron had a certain amount replaced by the process of "cementation," prior to casting.

This process, though producing the most regular and perfect steel, is a very costly one, and greatly kept back its general use.

For many years endeavours have been made to produce cast steel direct from the ore or pig of cast iron, by arresting the process of burning out the carbon at the proper moment, in place of burning it practically all out and then replacing a certain amount.

The "Bessemer" and "Siemens-Martin" processes are those in most general use, Krupp's process being somewhat similar to the latter.

The former of these especially has turned out large quantities of steel of the greatest practical use, but not of the highest grade.

The various methods are becoming improved continually and the whole subject is becoming more thoroughly understood, so that great strides are being made in the production of cheap steel of excellent quality by these varions processes or modifications of them.

It may be as well to give an outline of the various methods used first, by cementation and melting in crucibles giving "Crucible steel."

Wrought iron of good quality is made by puddling without previous refining; this is formed into bars, which are formed into "Blister steel" by the process of "*cementation*," in a converting furnace.

This furnace consists of two firebrick rectangular chests, 16 x 3 x 3 feet, placed alongside each other in an arched chamber, and surmounted by a wide conical chimney. One long fire-place of convenient form heats both chests.

In each chest the iron bars are laid half an inch apart, and imbedded in charcoal.

The whole is then plastered over with clay and kept at a glowing red heat for seven or ten days, according to whether a "mild" or "hard" steel is required, which depends upon the amount of carbon absorbed and *combined* with the iron, as much as $1\frac{1}{2}$ per cent. may be added in this way. The iron, when it comes out, forms "Blister* Steel" and was used in this condition. It was, however, not homogeneous in structure, and was improved by the process of being broken, piled and welded under the hammer, forming what is known to the trade as "shear steel," though according to modern nomenclature, it is still "wrought iron" or "piled metal."

To form this into *true steel*, it is broken up into lengths of about 5″ and about 40 or 50 lbs. placed into fire-clay crucibles, which have tight covers and are very carefully made, a little flux is added and glass to form an air-tight cover.

These are heated in powerful furnaces, and the molten contents is poured in a regular stream into cast iron ingot moulds.

Upon the regularity of the stream depends, in a great measure, the success of the operation.

The steel thus produced is the finest made, and at present is the only sort that can be used for high class cutlery.

Krupp's steel, which is used to an enormous extent, is a modification of the above method, by which he does away with the process of *cementation*, first, by employing a cast iron called "Spiegelessen," which contains 4 per cent. manganese and is peculiarly suited for the construction of steel, and then by a careful manipulation of the puddling process.

The puddling is performed at a lower temperature than for iron and under the most careful supervision, by which it is possible to arrest the process at the required point when sufficient carbon has been burnt out.

If the process is continued too long, too much carbon goes and ordinary soft wrought iron is formed.

* Old nomenclature.

It can here be seen how confusing the old nomenclature was, for iron at this part of the process forms a very hard *imperfectly puddled wrought iron*, that has the property of becoming harder on being heated and suddenly cooled in water, and would therefore have been classed as "steel," though uncertain in strength and utterly unhomogeneous in structure.

When the proper point is reached, the iron is withdrawn and worked under the hammer into bars, which are again broken up and melted as above in crucibles, and it is chiefly on account of the wonderful organization and the care exercised in the various processes that Herr Krupp has such a great name for his steel productions of all natures. It is the wonderful uniformity of quality with which he manufactures this steel in huge masses which constitutes the superiority of his productions.

We will next consider the "Bessemer" process; in this the steel is produced directly from cast iron by blowing air through it in a molten state in a converting vessel. His first idea was to use this process for the mechanical manufacture of wrought iron to supersede the expensive and very trying process of puddling, but he has hitherto failed in producing serviceable *wrought iron* by his process.

He thought that by stopping the process at various points he would get the various qualities of "steely irons" or *so-called* steels, and when *all* the carbon was gone, he would have wrought iron.

It is only with the very best *charcoal iron* (and possibly with "*spiegelessen*") that his first idea succeeds.

In practice the whole of the *carbon* and *silicon* is oxidized and then a definite quantity of carbon is added according to the nature of the required steel.

This is done by adding to the molten iron, when in the purest state (practically liquid bar iron) a definite quantity of liquid "*spiegelessen*" which has a known chemical composition, and thus the necessary quantity of carbon, also a proportion of *manganese* is added, the latter probably improving the quality.

The operation is carried on in a converter or "kettle," as it is called, it is a large, nearly cylindrical vessel of wrought iron lined with fire clay, and suspended on trunnions; its capacity varies from 3 to 10 tons.

In the bottom there are seven "tuyères" or blow holes, ½ inch in diameter, through which air is blown at a pressure of from 15 to 20 pounds per square inch.

The iron is run in in a molten state from a cupola or reverberatory furnace, and from the first is resting on a mass of air which rushes through it from the tuyères.

This air supplies oxygen to burn out the carbon, &c., which it does in about 15 minutes, and the "converter" is lowered to a horizontal position and from 5 to 10 per cent. molten *spiegelessen* is run in, which restores the proper amount of carbon to give the proper qualities to the steel.

It is up ended again and air blown through for a few minutes to secure its thorough incorporation, and the steel is then run into ingot-moulds. Steel made in this way is not sufficiently dense, and the blocks before becoming cool are placed under hammers, and are afterwards rolled into rails, tires, plates, &c., &c., but still the steel is *not good* enough for tools or even for the *springs* of railway waggons.

It is a very cheap process and an enormous quantity is used, the steel being infinitely better for *most purposes* than soft wrought iron.

The bulk of steel rails are made this way, one will last 20 wrought iron ones.

The next well known process is the "Siemens-Martin" process, which consists in melting pig iron along with malleable iron and Bessemer steel scrap; about 7 per cent. Spiegelessen being added towards the end of the process. The operation is carried on in the Siemens regenerative furnace, and the product is run into moulds. The furnace is a very ingenious one, but too long to describe. A modification of this plan is used in the Royal Arsenal as described in Morgan's hand-book.

There are various other processes and modifications of the foregoing in use, and improvements are being made every day in the old ones, but the product has the same general properties, it is homogeneous in structure and free from flaws or intermixed impurities.

The chief defect is that it is apt to contain air holes, and attempts have been made to get rid of these and other unaccountable irregularities of action, especially in "high" steels by casting under pressure.

A definite grain or fibre can be given steel by hammering or rolling it, and its strength along the fibre is greatly increased.

Steel can be more or less "tempered" by being first heated to redness and plunged into water. The more *carbon* it contains the *harder* it becomes. The degree of *hardness* depending on the *quality of the steel*, the nature of the *medium in which it is cooled*, and also upon the degree of heat imparted to the mass before hand. Thus the steel barrels for our guns are heated to between a *low red* and a *high heat* according to their quality, which is found by actual trial in the testing machine, and by being cooled in *oil* they are *considerably* toughened, if they were plunged in water they would be *harder* but extremely brittle.

Modern steel, regular in structure and free from flaws and impurities, is a very different substance from the old style of "steel" that except in small quantities was very uncertain in its action and expensive to manufacture, and only different from wrought iron in being *harder*.

We now have two definite parallel series of iron alloyed with carbon: The "*irons*" and the "*steels*" which are chemically identical. This distinction has long been made under another form by workmen who class the products of iron as "piled metal" or wrought iron and *ingot metal* or steel.

We can have steel according to the new ideas as soft as any wrought iron, but immensely superior in its properties and produced at a comparatively low cost.

This form of the metal has replaced wrought iron for guns and is received with favour even by Palliser.

CASTING SHELLS FOR RIFLED ORDNANCE.

Common shell are cast base downwards in an iron mould lined with sand and a little coal dust mixed.

The mould is made in two parts, the lower being merely a flat surface on which the upper portion rests, and the upper part, or body, which is a little longer than the shell.

An exact model of the shell is prepared, leaving an allowance for a small dead head at the fuze hole; it is oiled and sprinkled with black lead to prevent the sand of the mould adhering to it.

It is placed in position in the iron jacket, and sand and coal dust is rammed all around it, a channel is made down one side communicating with the base and widened at the top so that the molten iron flows to the bottom first, in a continuous and uninterrupted stream. Suspended in its proper position in the mould is the *core*, which is prepared as follows:

A core spindle of cast iron is supported by a rest in the axis of an iron core-box of the required shape. This can be opened or closed on the spindle. Small pieces of wood are placed in holes passing through the spindle, to prevent the core from being forced up the spindle by the molten iron as it rises.

A mixture of sand and coal dust is now rammed in. The gas generated by the coal dust prevents the iron entering the interstices between the particles of the sand. When full the box is opened and the core taken out, dipped in beer dregs and baked in hot air for about twelve hours. It then has a fine smooth surface.

The core spindle is hollow and perforated to allow the gas to escape from the core when it becomes heated. To preserve the hollow for the fuze hole the core spindle is covered with composition for the required distance.

The moulding box is pierced with a number of small holes to allow gas to escape.

The iron is melted in an iron cupola furnace. It is important that the channel through which the iron is poured should be larger at the top than bottom, so that there may always be plenty to supply shrinkage in cooling, and that too much may not run in at once and damage the core.

For this latter reason the hole is so arranged that the iron may rise evenly round the core and not displace it.

The shell is allowed to remain till it is set. It is then turned out and

the runner knocked off. It is now allowed to cool for twenty-four hours, when the spindle is taken out and the now brittle core removed and the shell cleaned.

All common shell in future will be cast to finished dimensions. This is easily done with a little care, so that the hard outside skin is not removed by turning.

The fuze hole is tapped and bush when necessary inserted.

The shell is lacquered inside with red lacquer. If for a Woolwich gun the holes for studs are bored and undercut, and the studs of gun metal in most cases are forced in by hydraulic pressure. Some are of brass and some of pure copper.

The position of the holes are made to correspond with the rifling of the individual gun, and great care is necessary to plane the studs to pass down the groove of a gun with increasing twist. The projectile is then prepared for a gas check and painted.

If the shell is for a B. L. gun the groove for the driving ring is cut and the ring pressed in.

PALLISER SHOT.

There was but little difference between Palliser shot and shell, and the latter are no longer made. The shell had a larger cavity than the shot, but were found too weak for strong armour.

The best mottled iron is used and is very carefully selected, so that when cast in "chill" it becomes intensely hard.

The peculiarity of these projectiles is their intense hardness, and the fact that they have no fuze hole in their head.

The iron used is of a harder description than that used for common shells.

The shot is cast point downwards to ensure the head being sound and dense.

The mould is so arranged that the head is cast in "chill," that is in iron, which quickly conducts away the heat and chills the metal rendering it intensely hard.

The body part is cast in sand and is therefore cooled slowly and does not become so hard as the head. The mould is made in two portions, the lower one is shaped somewhat like a mortar and is supported on trunnions, the upper portion fits on to it.

The lower portion or chill is made in two portions the "chill" of considerable thickness and the "lining," the lining is thin and can be replaced if worn.

The upper part is large enough to have sand rammed between the

iron case and the model of the base part of the shot or shell, The core is made of the same materials as before, but in a different shaped box.

It has fixed to it a tinned wrought iron brush arranged so as to come in its proper place in the shell to enable a hole to be tapped for base plug for gas check.

The metal is so hard even when not chilled that this is necessary.

Small cores of usual composition are inserted in the mould to preserve holes of proper form for the studs when required.

Steel pointed pins also are inserted in the head part to form the extractor holes for R. M. L. projectiles. In casting these projectiles the iron is allowed to flow directly into the cavity to form the shell. These projectiles are cast now to gauge having bands on them to full size.

The core is scratched out and the shell lacquered before it is cool.

When turned out of the mould they are covered with dry sand and allowed to cool slowly for 12 hours or more according to size, this anneals them and makes them less brittle.

An under cutgroove is cut round the wrought iron plug and a ring of lead hammered in to break joint and prevent fire entering.

From these projectiles being cast base up, they have to be very carefully examined for flaws or soft places in the base.

They are tapped all over with a pointed hammer. All natures of shot and shell are carefully gauged and examined.

STEEL PROJECTILES.

Cast iron being weaker than steel, the walls of shrapnel shells had to be made very thick, and in consequence, especially in the small sizes, there was but little room for bullets.

Palliser projectiles are found to break up on impact with heavy steel armour, and it is necessary to obtain something stronger. Forged steel projectiles have been experimented with in our service and have been largely adopted on the continent.

Steel bodied shrapnel are also made of different forms, some with bodies cast, others from drawn tubes.